Time-resolved X-ray Excited Optical Luminescence from Nanoscaled Systems and Related Phenomena

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This presentation reports some recent developments of a photon-in photon-out technique sometimes referred to as XEOL (X-ray Excited Optical Luminescence) in the energy domain [1] and TRXEOL (Time-Resolved X-ray Excited Optical Luminescence) in the time domain [2]. Recent applications of XEOL and TRXEOL in the studies of nanoscaled systems and related light emitting materials using both soft and hard x-rays and taking advantage of the time structure of APS in the top-up mode (2 ns pulse with 153 ns repetition rate) will be discussed. The experimental set up is shown in Fig.1 where the synchrotron pulse is used as the start for lifetime and time-gated measurements; in the latter, a time window in the decay curve is used to count the photons of interest.

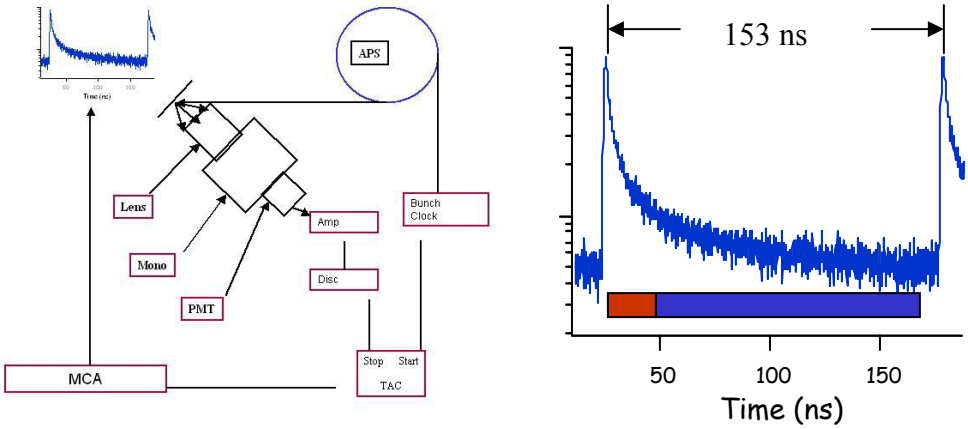

Fig.1 Schematic for XEOL and TRXEOL (left panel) and relatively fast (red) and slow (blue) decay time window (right panel)

XEOL is a technique ideally suited for the investigation of light emitting materials, especially when it is conducted at the synchrotron light source. It evolves from scintillation techniques used in the detection of high-energy ionizing radiations (e.g. x-rays, γ rays etc.). The availability of tunable x-rays with desired time structure from a synchrotron lights has made XEOL a powerful tool for the studies of light emitting materials in general and nanoscaled systems (most nanostructures of semiconductors and even some metals are light emitting materials) in particular.

Nanomaterials are substances with one to all three dimensions in space confined to the size of the order of nanometers. At these dimensions, an effect often known as quantum confinement kicks in and electrons confined in the systems begin to behave differently from their bulk counter parts. For example, bulk silicon is not a light emitter in the visible

while Si nanostructure in the form of porous silicon and silicon nanowires emits light in the visible upon photo-excitation. Excitation with soft x-ray energies across the Si K-edge induce site specific luminescence, which in turn reveals the origin of the luminescence (Fig.2, left panel). The corresponding TRXEOL measures the decay lifetime and the time- gated luminescence (Fig.2, right panel) and the X-ray Absorption Near Edge Structures (XANES) monitored with time-gated optical photon yield.

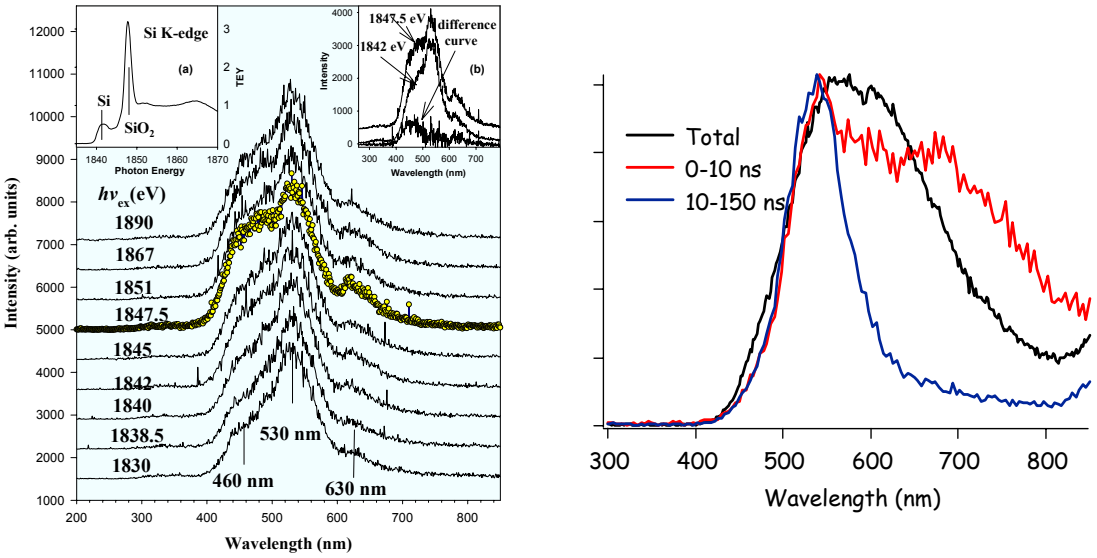

Fig.2. XEOL from silicon nanowires (left panel) excited with photon energies across the Si K-edge, the insets show the XANES and the excitation-channel dependent luminescence. The time-resolved XEOL of silicon nanowire (right panel) shows the time-dependent luminescence for the fast (red) and slow (blue) time window and the total.

The talk is organized as follows. An introduction presents the background of the technique and its present status followed by a description of the instrumentation implemented at the APS. After that, the relevance of XEOL in the study of nanoscaled systems is discussed and examples of recent applications in a number of nanoscaled systems such as Si, III-V (GaN) and II-VI (ZnS, CdS) compounds, etc. is presented. Emphasis is placed on the site specificity and time-gated spectroscopy and their implications. Other related issues such as soft vs. hard x-ray XEOL and applications to organic light emitting materials and soft matters will also be noted. The talk ends with a discussion of the prospects of the technique and potential future scientific programs that can be implemented at the APS.

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[1] Sham et. al. Phys. Rev. B 70, 045313 (2004).
[2] R.A. Rosenberg, G.K. Shenoy and T.K. Sham, VUV 14 presentation and abstract Cairns, Australia, July 19-23 (2004).